JET FRAGMENTATION AND MLLA

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Recent CDF results on inclusive momentum distributions and multiplicities of particles in restricted cones around jets are compared to predictions using the Modified Leading Log Approximation. We found that MLLA gives a very reasonable description of jet fragmentation for a wide range of energies. Model parameters are extracted separately from the multiplicity and from the shape of the momentum distributions and are found to agree. The ratio of charged particle multiplicities in gluon and quark jets measured in the context of MLLA is compared to the model-independent result and also found to agree.

1 Introduction and Theoretical Background

Perturbative QCD calculations, carried out in the framework of the Modified Leading Log Approximation [1] (MLLA), complemented with the Local Parton-Hadron Duality Hypothesis [2] (LPHD), predict the shape of the momentum distribution, as well as the total inclusive multiplicity, of particles in jets. The MLLA is an asymptotic calculation, which proves to be infrared stable, in the sense that the model cutoff parameter Q_{eff} can be safely pushed down to Λ_{QCD}. LPHD is responsible for the hadronization stage and implies that hadronization is local and happens at the end of the parton shower development. In its simplest interpretation, the model has one parameter K_{LPHD}, the rate of parton-to-hadron conversion:

$$N_{hadrons} = K_{LPHD} \times N_{partons}. \tag{1}$$

The low cutoff parameter Qeff allows the inclusion of hadrons with low transverse momentum, which constitute the majority of all hadrons in jets and could not be controlled in ordinary pQCD with a conventional cutoff scale of the order of 1 GeV. In the most favorable scenario, $K_{LPHD} \sim 1$. If only charged particles are observed, one may expect $K_{LPHD}^{charged}$ to be between 1/2 and 2/3.

In MLLA, momentum distributions and multiplicities in quark and gluon jets in a restricted cone of size θ around the jet axis are functions of $E_{jet}\theta/Q_{eff}$ [3] and differ by a factor r:

$$N^{q-jet}(\xi) = \frac{1}{r} N^{g-jet}(\xi), where\ \xi = \log\frac{1}{x}, x = p_{track}/E_{jet} \tag{2}$$

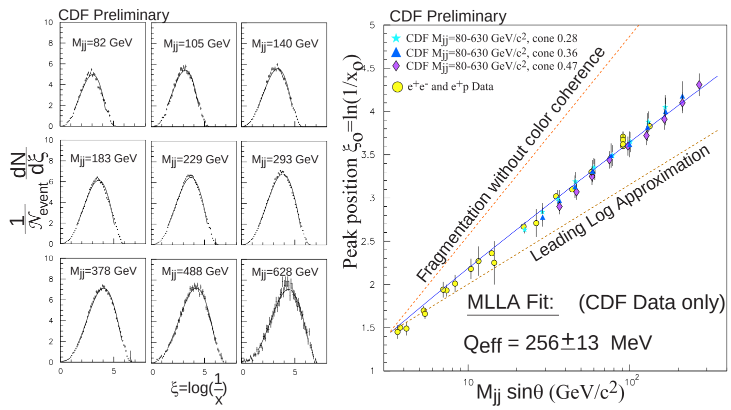

Figure 1: Left: Momentum distribution of charged particles in dijet events. Fitted with MLLA function for Q_{eff} and K; Right: Peak position vs $M_{jj}\sin\theta$.

Jets at the Tevatron are a mixture of quark and gluon jets. Therefore,

$$N^{charged}_{hadrons}(\xi) = K^{charged}_{LPHD}(\epsilon_g + (1-\epsilon_g)\frac{1}{r})F^{nMLLA}N^{q-jet}_{part}(\xi) = KN^{q-jet}_{part}(\xi) \quad (3)$$

where ϵ_g is the fraction of gluon jets in the events, the factor of $1/r$ reflects the difference between gluon and quark jets, and, finally, factor F^{nMLLA} accounts for the next-to MLLA corrections to the gluon spectrum. Theoretical calculations[4] predict somewhat different values of F^{nMLLA}, but all agree that F^{nMLLA} has almost no dependence on the jet energy in the region relevant to this analysis. We chose the average of the results above and used the difference between predictions as a theoretical error: F^{nMLLA}=1.3±0.2. The same papers predict the value of r to be between 1.5 and 1.8.

2 Dijet Data Analysis

We used data collected by CDF during the 1993-1995 running period. For the analysis, we selected events with two jets well balanced in transverse energy. Both jets were required to be in the central region of the detector to ensure reliable tracking reconstruction. To avoid biases, third and fourth jets were allowed if sufficiently soft. Data was further subdivided into 9 dijet mass bins (mea values were ranging from 80 to 630 GeV). Tracks were counted in restricted cones of sizes 0.28,0.36 and 0.47 around the jet axis. Fig. 1(left) shows the inclusive mometum distribution of charged particles in jets for the 9 dijet mass bins for the largest cone-size of 0.47. The data was fitted with

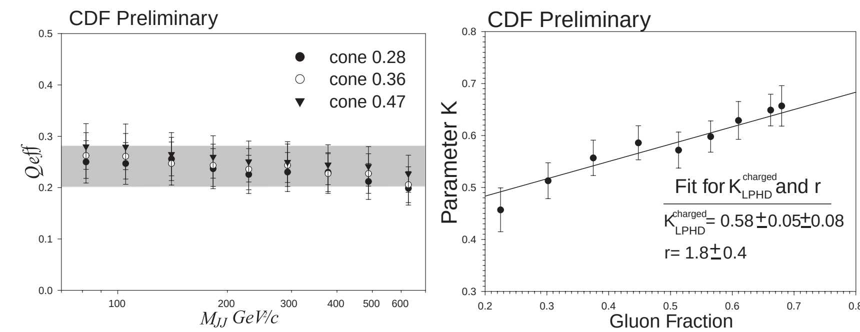

Figure 2: Left: Fitted values of Q_{eff} for 27 combinations (9 dijet mass bins x 3 cone-sizes). Errors are dominated by correlated systematic uncertainties; Right: Fit of the parameter K for K_{LPHD} and r. Cone 0.47. First error is combined statistical and systematic errors, the second one - theoretical error coming from F^{nMLLA}.

Eq.(3) for the parameters Q_{eff} and normalization K (see Eq.(3)). The visual agreement is good; however, the χ^2 is generally large indicating the importance of higher order and hadronization effects. We separately fitted the position of the peak of the momentum distribution for 27 combinations (9 dijet mass bins x 3 cone-sizes). In MLLA, the peak position depends on Q_{eff} and is predicted to have $E_{jet}\theta/Q_{eff}$ scaling. In Fig. 1(right), we plotted the dependence of the peak position on $M_{jj}\sin\theta$ (e^+e^- and ep data is shown as well). Clearly, the predicted scaling is present in data. Fig. 2(left) shows the 27 fitted values for Q_{eff} as a function of the dijet mass. Taking into account that the errors are dominated by correlated systematics, one can conclude that Q_{eff} is not absolutely universal, which again may be an indication of higher order effects. However, the scale of the deviations is very moderate suggesting that these effects are not large. We report a value for $Q_{eff} = 240 \pm 40$ MeV (corresponding range shown as a band on Fig. 2(left)). Analysis of the fitted parameter K allows an extraction of both K_{LPHD} and r. According to (3), the dependence is linear.On Fig. 2(right), we plotted 9 values of K (corresponding to 9 dijet masses for the largest cone-size 0.47) vs the gluon jet fraction (extracted using Herwig 5.6) in the events from respective dijet mass bins, as well as the results of the fit for K_{LPHD} and r. The same parameters can be extracted from the inclusive multiplicity using an integrated version of Eq.(3). In this case, the extracted parameters will only rely on the total multiplicity and not on the exact shape of the distribution. Fig. 3(left) shows the fit of data with MLLA predictions as well as the fitted parameters K_{LPHD} and r. It is remarkable that the two results are in such a good agreement.

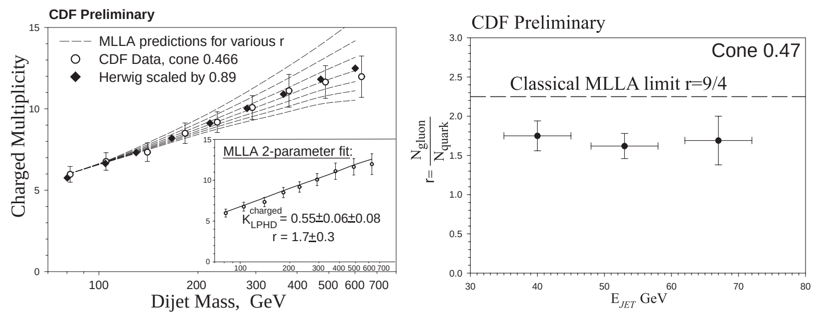

Figure 3: Left: Charged particle multiplicity (per jet) as a function of the dijet mass. MLLA fit for K_{LPHD} and r; Right: ratio of charged multiplicities in gluon and quark jets based on comparison of the dijet and γ-jet events.

3 Model-independent Measurement of r

We compared the multiplicity in dijet and γ-jet events (data selection was similar) to extract model-independent measurement of r. These samples have very different fraction of gluon jets for the jet energies 40-60 GeV (roughly 60% for dijets and 12% for γ-jet, according to Herwig 5.6). The multiplicities measured for each of the samples and a knowledge of the gluon jet fractions allowed us to extract r. Fig. 3(right) shows the measured r as a function of the jet energy. We report r=1.75±0.11±0.15 in perfect agreement with MLLA result.

Conclusion

Results presented support the perturbative nature of jet fragmentation. The measured value of Q_{eff} allows a consistent description of the majority of particles. K_{LPHD} and r are not only self-consistence within the model, but also with model-independent result. $E_{jet} \sin\theta$ scaling is observed for the first time.

References

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